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Country and regional staple food price indices for improved identification of food insecurity

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ABSTRACT

Large price increases over a short time period can be indicative of a deteriorating food security situation. Food price indices developed by the United Nations Food and Agriculture Organization are often used to monitor food price trends at a global level, but largely reflect supply and demand conditions in export markets. However, reporting by the United States Agency for International Development's Famine Early Warning Systems Network indicates that staple cereal prices in many markets of the developing world, especially in regions that are food insecure areas, are isolated from international export market price trends. Here we present country and regional staple food price indices compiled for improved food security monitoring and assessment, and specifically for monitoring conditions of food access across diverse food insecure regions. We examine the market integration of regional and country level staple food price indices for 35 countries in West, East and Southern Africa and in Central Asia and Central America. We found that cereal price indices constructed using local market prices of within a food insecure region showed significant differences from the international cereals price, and had a variable price dispersion across markets within each marketshed. This work supports the need for improved decision-making about targeted aid and humanitarian relief, by providing earlier warning of food security crises.

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1. Introduction

There have been two sharp rises in food prices around the globe during the past few years. In 2008, prices for grains and oilseeds reached very high levels after production shortfalls occurred in several exporting countries, markets panicked, leading to bans on food crops exports by some major exporters and hoarding by food import-dependent countries. The United Nations Food and Agriculture Organization (FAO) estimated that the food price increase in 2007–08, drove the number of undernourished people worldwide from 915 million to more than 1 billion, the highest number in more than 40 years (FAO, 2009). World food prices rose sharply again at the end of 2010, hitting an all-time high in February 2011 (Vrieling et al., 2011), resulting in a significant increase in food insecurity around the world.

To monitor these changes, the FAO has developed a food price index to monitor food commodity price trends at a global level, but it largely reflects supply and demand conditions in export markets in the developed world and the most advanced countries of the developing world. A component of the FAO Food Price Index, the FAO cereals price index is an indicator of price trends in globally-traded cereals but only poorly reflects variations in the least expensive food often consumed by the poor in food-insecure countries (Brown and Funk, 2008; Funk and Brown, 2009a). Prices of staple foods in food-insecure regions often do not immediately follow international export market price trends, due to imperfect market integration, prices for local products moving between the export and import parity price bounds, an absence of imported products, and/or policy barriers to trade (Conforti, 2004; Minot, 2011). Here we develop new staple food price indices focused on highlighting prices that are relevant to food security analyses and explore how different combinations of food categories and markets impact local price dynamics. Our indices were developed in order to provide policy-makers concerned with food security monitoring with reliable information on staple food price changes in food insecure regions.

Regional differences in market integration make global FAO price indices less effective for monitoring changing food access and

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food security conditions for the poor in the developing world. As the global commodity market changes, it is important to have better tools for monitoring the potential impact of increased variability on overall prices. Here we construct regional staple food price indices, assess the empirical relationship between the new indices and the FAO cereal price index, and analyze methods for anticipating future, local food prices through models incorporating local growing conditions and international prices.

1.1. Price indices and their development

A price index is a normalized, weighted average of prices for a given class of goods during a period of time. Food price indices are based upon weighted averages of food commodity prices in international export markets, expressed in terms of their value in a base period, and calculated on a monthly basis. The food price indices of the FAO the International Monetary Fund (IMF), and the World Bank (WB) are indicators of worldwide trends in food commodity prices, and are often used to indicate the ability of the poor to purchase food in a variety of locations. All three indices are constructed using the same formula (Laspeyres index), but the sets of commodities and markets that they include, as well as the weights that are assigned, vary depending on the index. The FAO cereals index used in this study comprises wheat, maize, and rice. To take into account the importance of the wheat, maize, and rice prices used in the index, the commodities are weighted with world export shares in 2002–04, as provided by the FAO statistical database.

The weakness of any index is that it does not allow a user to understand which component of it is contributing most, or least, to the global changes it shows. Some index components may not contribute significantly to the overall index trend. For cereals, for example, it appears that a smaller set of commodity prices than used in these three indices would suffice to observe largely the same general price trends. A regression of month-to-month changes in the FAO cereals price index on month-to-month changes in three export cereal price quotes (no. 2 hard red winter wheat – f.o.b. Gulf, no. 2 yellow maize – f.o.b. Gulf, and Thai rice 100% B – f.o.b. Bangkok) shows that these three prices explain about 85 percent of the variation in that index.

1.2. Spatial price analysis

The purpose of this paper is to develop new staple food price metrics for food security monitoring, and to understand the variability and contribution of country-level input data to the proposed food price indices. To conduct these analyses, we use spatial price analysis tools, which are mainly concerned with examining how markets perform over space and time. At the heart of the analysis is the law of one price (LOP), which posits that if regional markets are linked by trade and arbitrage, they will have a common, unique price (Fackler and Goodwin, 2001). In developing countries, price analysis is often concerned with investigating two other concepts, market integration and market efficiency, linked to the LOP. Following Fackler and Goodwin (2001), this study considers market integration as the degree by which a shock in one market is transmitted to another market. For example, if two markets are highly integrated, we would expect that a supply shock in one market would have a strong effect on prices in another market. In mathematical notation, we can think of this as a transmission ratio (TR) denoted:

$$\mathrm{TR}_{\mathrm{AB}} = \frac{\partial P_{\mathrm{B}}/\partial \varepsilon_{\mathrm{A}}}{\partial P_{\mathrm{A}}/\partial \varepsilon_{\mathrm{A}}} \tag{1}$$

where P_{A} and P_{B} are the prices in each region and ε_{A} is the supply shock that has occurred. If markets are perfectly integrated, the transmission ratio will be one. The concept of market efficiency is different in that it normally considers the allocation of resources and aggregate welfare. If a market is efficient, then the "allocation of resources is such that aggregate welfare cannot be further improved upon through a reallocation of resources" (Fackler and Goodwin, 2001). In a spatial sense, one can think of this as implying that no further arbitrage opportunities exist for spatial traders.

1.3. Granger-causality

Researchers have proposed many empirical tools to test market performance. Early studies relied on correlation analysis to determine the degree of co-movement between prices. It was posited that if spatial markets were integrated, then their prices would tend to move together. However, this approach was criticized as many common components (inflation, climate patterns and population growth) can exert similar influence over of prices, even if markets are not linked. At the opposite end of the spectrum, monopoly procurement at fixed prices may result in correlation coefficients of 1.0, regardless of the degree of interaction between markets (Harriss, 1979 referenced in Fackler and Goodwin, 2001). The technique also cannot distinguish between markets in which delivery lags produce a lag in the price response between markets (Barrett, 1996).

Granger-causality has been used to study grain market integration in West Africa. If lagged prices from a market (j here) are useful in forecasting prices in another market (i here), even after controlling for own-lagged prices in the market i, then market j is said to Granger-cause price movements in market i. The procedure is usually carried out within the framework of a bivariate regression, a vector autoregressive or error-correction model and confirmed or rejected with an F-test on estimated coefficients. Some analysts have taken the presence of Granger-causality to mean that shocks to prices in one market may induce a significant response in another, with a lag. Others have considered it as an indicator of the flow direction of information between markets. Baulch (1997a,b) adds that if two-way Granger-causality exists, then prices are simultaneously determined (Baulch, 1997a). However, Fackler and Goodwin (2001) point out the test only allows inferences about lead/lag relationships and little can be said about the causal framework that underlies the dynamic adjustments.

1.4. Price volatility

Commodity markets have long been characterized by high volatility in small, isolated agricultural markets in regions. Variability the short term, is caused by a mismatch between the timing of supply (which is seasonal) and demand (which is more constant) (FAO, 2011b). Over the longer term, broader issues of agricultural production and population growth will drive up food prices, which provides incentives for farmers to produce more at a variety of scales. Volatility, however, can also be caused by poor market information and lack of adequate stocks to provide additional supply during times of scarcity. Increases in food prices over the medium term causes both food price spikes and increases in volatility across the commodity markets (von braun and Tadesse, 2012). Here we examine volatility through the standard deviation of the price across all markets in the index during each time step to provide an idea of the dispersion of prices across the marketshed. In future analyses we will examine whether certain markets transmit prices faster than others and the geography of the price transmission, but in this paper we focus on presenting regional price indices for food security analyses.

We use Granger causality to assess market integration, and then estimate local, national and regional price variations that are most highly related to the local prices most relevant to local food insecure communities. The method proposed here is focused on demonstrating the limitations of the FAO cereal price index, and proposing new local and regional food price indices that are more relevant for food security analysis. The alternative staple food price indices use data from regional and local markets and non-cereal commodities most often consumed by the poor in food-insecure countries in order to better reflect how changing food prices affect food security (Alem and Söderbom, 2012). Regional price indices provide new information that is currently lacking from the global price indices, and enable a much improved measure of access to food by the most food insecure populations in these regions (Schmidhuber and Tubiello, 2007; Tschirley and Jayne, 2010).

2. Data

The new local, national and regional indices produced in this paper use information from a continuously updated price database comprised of food prices from 232 markets in 35 countries, collected by the FAO and the US Agency for International Development's Famine Early Warning Systems Network (FEWS NET) (Fig. 1). Most of the data is available from the FAO at the Global Information and Early Warning System (GIEWS) website: http://www.fao.org/giews/pricetool2/. There are several data sources for each country's information. While a portion of the data can be downloaded from FAO/GIEWS's PriceTool web site, not all of the data is available at this public database. While the FAO and FEWS NET use the same data sources (Ministries of Agriculture), and most of the data is publicly available in some form (from newsletters, websites, and by request from local Ministries or from the World Food Program), it is not available from any one source in its complete, constantly-updated form, and thus is a unique dataset. There are 124 different commodities in the database from which we draw for the study. FEWS NET experts deemed these commodities as appropriate to assess food security in the selected area.

FEWS NET has offices in 23 countries, and has food security monitoring responsibilities in many of the countries represented in this study (Brown, 2008). The database has retail price data in local currencies from 1997 to 2011, but the starting year of each series varies by market. We use the most complete information from 2004 through 2011 to form the price indices.

2.1. FAO cereals index

While the FAO Food Price Index is more known globally, the FAO cereal price index most closely approximates the food security-related indices we are building, because the commodity baskets in our price databases and our analyses were selected based on staple foods that dominate the diet of the poor. The FAO cereal price index combines maize, wheat, and rice price indices (Trostle, 2010) and is composed of one maize export price quotation, a combination of nine wheat price quotations, and the Rice Price Index that combines the prices of three varieties of rice (Japonica, Aromatic, and Indica), for a total of 16 price quotations (FAO, 2011a). The index is based upon weighted averages of cereal commodity prices in international export markets, expressed in terms of their value in a base period (2002–2004), and calculated on a monthly basis. The average price in the base year of 2006 was used to create a nominal FEWS NET staple food price index for every market and commodity combination.

We also use the FAO cereals index to predict future changes in the FEWS NET food price indices by country, to provide early warning of price increases in specific food insecure areas. We

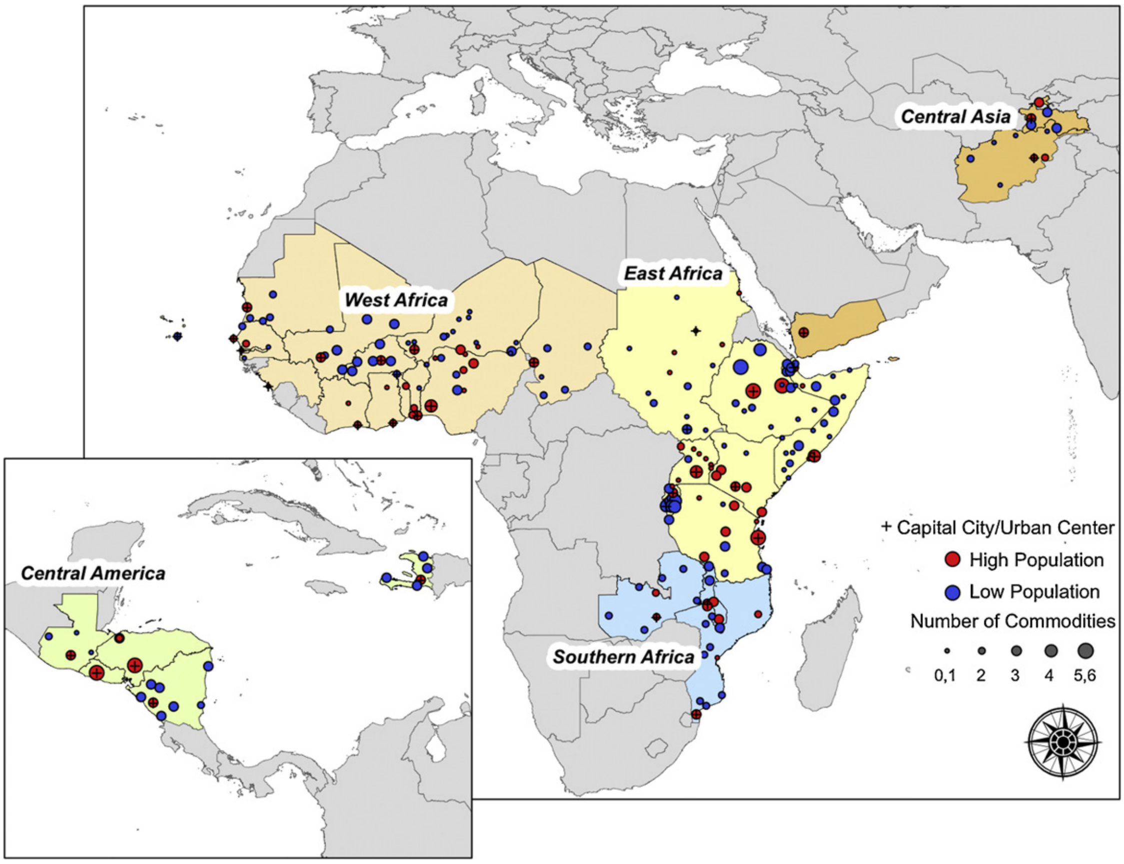

Fig. 1. Map of markets with commodity prices used in the staple food price indices.

Table 1
Summary of price information by country, including commodity used in the index, average price, standard deviation, minimum and maximum price during the 2004–2011 period, the number of periods in the average, and the number of markets in each country's price index. When there is only one market, it is the capital city of the country. Information on cereals is also provided, including production and import information in metric tons from 2005 to 2009 for maize, rice and wheat, the three commodities in the cereals price index.

Country	All commodities	Ave[a]	Std dev[d]	Min[d]	Max[d]	Number of periods[d]	Number of markets in index	Ave 2005–09 maize prod[b]	Ave 2005–09 maize imports[c]	Ave 2005–09 rice prod[e]	Ave 2005–09 rice imports[c]	Ave 2005–09 wheat prod[e]	Ave 2005–09 wheat importsimports[c]
El Salvador	White Maize, Rice (de primera), Red Beans	129.11	30.42	82.72	196.48	88	1	764,660	32,788	0	523,930	4207	227,410
Guatemala	White Maize, Rice, Black Beans	131.54	23.97	97.58	168.69	69	6	1,395,300	27,493	9082	669,820	1812	462,950
Haiti	Rice (Imported), Black Beans, Maize Flour	114.09	21.86	78.84	170.15	76	5	221,100	116,650	0	8834	3342	208,650
Honduras	White Maize, Classified Rice, Red Beans	133.78	33.12	70.24	204.17	88	4	545,540	37,628	1051	304,360	1924	177,320
Nicaragua	White Maize, Rice (80/20), Red Beans	142.04	46.18	63.81	248.43	88	5	498,010	305,150	0	86,669	3934	114,980
Afghanistan	Wheat Flour, Wheat	133.4332	52.92	72.18	285.57	88	7	322,800	0	3,960,000	1639	566,800	511,400
Tajikistan	Wheat Flour First Grade, Rice, Potatoes	125.95	46.05	53.77	205.24	88	5	140,740	56,091	701,130	0	0	305,960
Yemen	Wheat, Rice, Red Beans	137.85	36.95	97.62	252.53	63	1	61,100	0	174,650	364,440	189	2,338,400
Burundi	Cassava Flour, Maize, Sweet Potato, Beans	120.49	23.65	82.55	175.22	68	6	121,080	72,019	8334	23,017	1	6744
Djibouti	Sorghum Flour, Wheat Flour, Rice Belem	136.25	37.71	88.72	219.52	88	6	11	0	0	721	0	123,230
Ethiopia	White Maize, White Sorghum, Mixed Teff, White Wheat	158.75	76.16	69.62	329.43	88	13	3,790,400	16,784	2,568,700	42,627	4122	964,850
Kenya	White Maize, Sorghum, Beans	114.16	28.16	71.12	178.53	88	8	2,777,600	47,771	315,280	421,370	126,120	652,130
North Sudan[d]	Sorghum	134.13	52.92	58.24	239.6	85	8	63,400	24,300	623,340	59,714	3127	1,479,400
Rwanda	Maize, Beans, Rice	111.77	29.10	54.57	170.62	84	2	148,710	76,040	41,285	30,283	1879	9244
Somalia	Red Rice (Imported), Red Sorghum, White Maize, Cowpea	215.06	134.42	83.48	564.3	88	21	121,570	17,985	1016	73,474	0	6322
South Sudan[e]	Sorghum, Maize, Wheat Flour	145.45	59.12	82.86	346.37	63	8	-	-	-	-	-	-
Tanzania	White Maize, Rice	116.59	35.40	55.96	188.21	86	13	3,418,700	1,279,200	94,720	75,277	45,300	641,430
Uganda	Maize, Beans, Cassava Chips	126.45	48.65	73.2	363.7	88	5	1,245,600	170,520	18,200	25,437	43,817	356,580
Malawi	White Maize, Rice, Cassava	117.30	44.23	52.78	212.7	88	9	1,245,600	170,520	18,200	25,437	43,817	356,580
Mozambique	White Maize, Rice, Beans	122.93	39.69	62.78	204.05	88	9	1,345,800	109,950	2465	125,770	0	417,150
Zambia	Maize, Maize Meal	117.04	29.21	75.42	177.98	88	9	1,351,100	22,314	131,070	40,630	12,882	50,653
Benin	Maize, Rice, Cowpea	123.91	28.87	79.26	194.25	88	5	903,650	95,497	0	1500	9770	14,723
Burkina Faso	Millet, White Maize, Sorghum	114.45	26.34	67.68	192.25	88	6	825,560	136,960	0	4127	38,570	44,101
Cape Verde	Maize, Rice	121.82	25.20	97.64	168.98	88	1	5959	0	0	8412	2217	22,931
Chad	Pearl Millet, Maize, Sorghum	108.80	24.34	61.46	164.59	88	6	204,310	132,420	6515	8412	0	23,525
Côte d'Ivoire	Rice, Yams	114.10	23.47	86.52	190.13	84	2	615,690	678,770	0	16,642	195,860	302,160
Gambia	Rice	120.66	16.75	99.44	155.33	64	1	37,536	35,531	0	52	78,474	52
Ghana	Cowpea, Yams	176.71	65.48	72.12	321.52	64	2	1,333,900	283,140	0	46,314	343,800	351,230
Guinea	Rice	93.89	30.68	30.92	173.16	88	1	632,420	1,409,500	0	2482	74,863	42,235
Mali	Millet, Rice, Sorghum	106.51	17.04	73.09	147.23	88	8	840,640	1,331,300	10,041	7438	100,890	68,685
Mauritania	Wheat, Rice (Imported), Maize	126.48	19.82	91.19	169.16	88	6	14,755	72,072	2198	1925	64,825	297,280
Niger	Maize, Millet, Sorghum	110.80	22.14	67.83	182.69	88	14	5979	52,085	8234	28,304	16,079	10,911
Nigeria	Maize, Sorghum, Cassava, Cowpea	124.30	33.95	62.87	213.89	88	10	6,929,000	3,675,300	54,163	5613	53,754	3,937,900
Senegal	Millet, Broken Rice	118.04	23.06	73.75	181.95	88	5	293,160	314,660	0	102,850	847,130	372,180
Togo	Maize, Cowpea	142.11	53.39	65.6	313.2	87	2	568,140	86,164	0	1950	28,367	77,675

[a] Average, standard deviation, minimum and maximum statistics of country-index for all food products listed given in price per kilogram per month in local currency over period.
[b] Annual Production in metric tons, averaged over 2005–2009.
[c] Annual Imports in metric tons, averaged over 2005–2009.
[d] North Sudan production and import numbers for all of Sudan.
[e] See North Sudan for production and import statistics.

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report the highest significant lagged correlation coefficient (r^2) after testing lags between 1 and 12 months for each country. The predictive capability of the FAO cereals index alone was compared to a linear regression with both the FAO cereals index and the vegetation index for the previous growing season used as parameters.

Using first differenced data, we use a one-tailed *F*-test, with an alpha of 0.05, to test if the vegetation index significantly improved the model. After first-differencing the price data, eighty-eight observations remain, minus the lag shown in Table 1. We estimate two parameters in the FAO Cereal Index regression, and three parameters in the vegetation index augmented model.

To estimate the impact of the FAO cereals index and vegetation index on staple food prices, we used an OLS linear regression model on the country-level indices. We trained the model using the annual NDVI, the country staple food price index and the FAO cereal prices through 2008, and used the modeled coefficients to estimate the country staple food price index from 2009 to 2011.

2.2. Vegetation data

Satellite remote sensing of vegetation greenness was used in a cross correlogram analysis to assess growing conditions in the area around each market. We used an average of five MODIS Climate Model Grid (CMG) 0.05 degree (Brown et al., 2006a; Justice et al., 1998) maximum value monthly vegetation index pixels around each market to represent the growing conditions in the region (Brown et al., 2006b). The data were summed over the growing season to create an annual indicator of the growing conditions. The data are used as an proxy for rising and falling cereal supply in regions with late or unreliable production statistics for locally grown staple cereals (Fuller, 1998; Funk and Budde, 2009). In semi-arid ecosystems, satellite-derived vegetation data is highly correlated to rainfall and overall ecosystem productivity, and can be used to estimate crop yields (Becker-Reshef et al., 2010; Dregne and Tucker, 1988; Farrar et al., 1994; Kerr et al., 1989; Santos and Negri, 1997; Tucker and Choudhury, 1987). Previous research on estimating variations in food prices show satellite

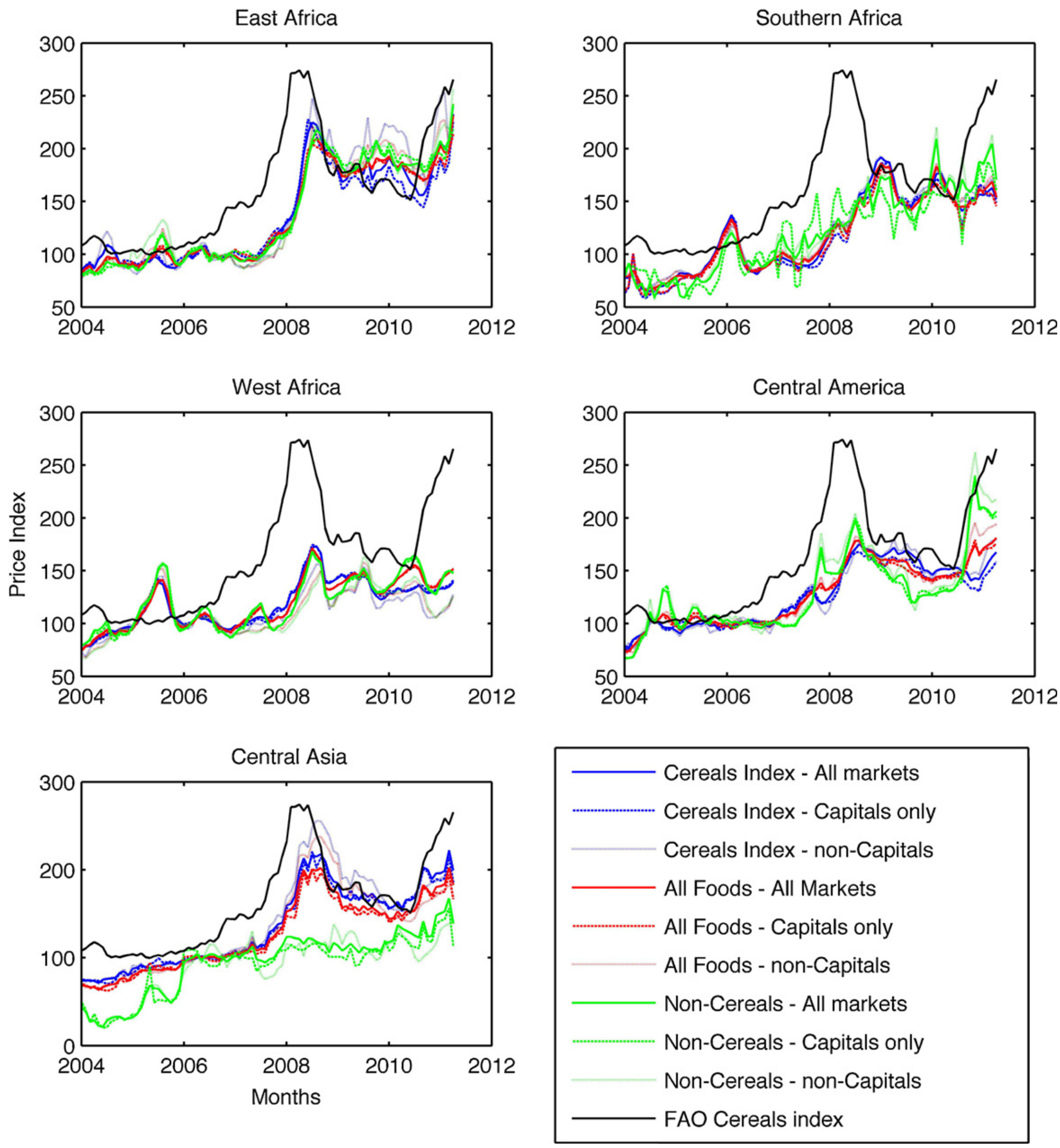

Fig. 2. (A) Regional price indices for each of the five food insecure regions. In each figure, the cereals, non-cereals, and all commodities, and the capital city markets, non-capital city markets and all markets are given, along with the FAO cereals price index for reference.

remote sensing of vegetation as an important and significant parameter in estimating variation in food prices (Brown et al., 2006b, 2009a, b). Unlike satellite derived rainfall estimates, vegetation observations are not reliant on daily, spatially extensive ground rainfall observations, which are usually lacking in developing countries that have food security crises. Satellite remote sensing data also have the advantage of being an early indicator of drought and weather-related production changes across multiple agroecosystems (Monfreda et al., 2008; Zaal et al., 2004), and is used operationally by both USAID's FEWS NET and the FAO to assess food production (Brown, 2008). Vegetation index estimates of the growing season are often available months before agricultural production statistics.

3. Methods

We combined the food price data into indices using information on local production systems and patterns of food consumption.

- National Cereals Price Index for 35 food insecure countries, constructed using prices of commodities that are important in the diet of food insecure communities (see Table 1);
- Regional indices for West Africa, Southern Africa, East Africa, Central America and Central Asia for:
  - o cereals only, non-cereals only, and all food prices available indices
  - o capital cities only, non-capital cities and all markets indices

Regional indices were constructed to compare directly to the FAO cereals index for five regions (Fig. 1), and to include markets (all non-capital cities) and commodities (all food prices which were not maize, wheat and rice) to highlight the relevance of our regional price indices for food security. FEWS NET Production and Market Flow Maps were used to classify markets into major surplus, minor deficit, and major deficit zones in each country, creating marketsheds. Fig. 1 shows these regions and defines the input countries for the Eastern, Southern, Western Africa regions, as well as the Central American and Central Asian regions. Table 1 provides information on the price data used as an input into the regional marketsheds, along with specific information about the price data inputs for each country. The trade flow maps can be found on the FEWS NET website (www.fews.net) under markets and trade.

The number of data observations available from January 2004 to April 2011 was used as a weighting factor for each market and commodity combination, reducing uncertainty in the staple food price indices due to missing information. We then average commodity price indices to form a country price index for each country. We use a similar method to create regional indices. The selected time period captures more than 75% of the price data from 18 of the 35 countries, between 50% and 75% of the price data from 10 of the countries, and between 25% and 50% of the price data from 6 countries. The database holds only few observations of food price data from the early 2000s and before. Because of missing values for some commodity-market pairs, the composition of country and regional price indices may differ from one period to another. However, in general, these differences are minor. Instead of inputting missing values, we chose to use an unbalanced panel data set. The FEWS NET price indices reflect the average rate of price change for a bundle of key staple cereals that are consumed in each food insecure country. These are reported in Table 1, along with the average production and imports of wheat, rice and maize from 2005 to 2009 for all countries.

Although an additional weighting of commodities based on the importance of a commodity in terms of caloric contribution to local people between marketsheds would be preferable, it is not available for the market/commodity pairs we use here. Traded volumes or "traded value" information are often used in other price indices to judge the economic importance of a commodity (IMF, 2009). In this study, however, we are more interested in consumption volumes by the poor rather than volumes traded. Some of the commodities included in the indices (cassava, for example) are often not extensively traded but consumed locally. Many of the non-cereal commodities we use in these indices are low-value, bulk, semi-processed commodities. Often the volumes of these commodities are difficult to measure, particularly in areas with excessive informal trade, such as in Southern or Western Africa, or where there are large domestic trade flows between regions of the country, such as in Ethiopia.

3.1. Analysis methods

We used Granger-causality tests to assess the statistical relationship between regional marketsheds and the global cereals market. If a regional market is Granger caused by the FAO index, we

Table 2
Results of the Granger causality test, presenting the *F*-test probability for the regional staple food price indices for cereals, non-cereals and all commodities, and for all markets, capital cities only and non-capital cities. Statistically significant results are shaded grey.

Region	Cereals		Non-Cereals		All	
	Granger-caused by FAO index	Granger-causes FAO index	Granger-caused by FAO index	Granger-causes FAO index	Granger-caused by FAO index	Granger-causes FAO index
	Prob > *F*	Prob > *F*	Prob > *F*	Prob > *F*	Prob > *F*	Prob > *F*
All markets						
East Africa	0.0000	0.2315	0.1512	0.0556	0.0009	0.1395
Southern Africa	0.6836	0.6400	0.0273	0.4985	0.6158	0.6147
West Africa	0.1294	0.1898	0.6521	0.4986	0.2971	0.4735
Central America	0.0115	0.4476	0.0020	0.9730	0.0008	0.5596
Central Asia	0.0005	0.3129	0.5477	0.2181	0.0010	0.1858
Capital cities						
East Africa	0.0073	0.0046	0.1698	0.2382	0.0544	0.0702
Southern Africa	0.9421	0.7931	0.1406	0.0795	0.6459	0.5378
West Africa	0.3166	0.1972	0.5557	0.5567	0.2834	0.5671
Central America	0.0059	0.4231	0.0068	0.7433	0.0033	0.5540
Central Asia	0.0007	0.7871	0.4787	0.7283	0.0024	0.5366
Non-capital cities						
East Africa	0.0027	0.5117	0.0236	0.1600	0.0083	0.3410
Southern Africa	0.5470	0.5028	0.0638	0.7181	0.4435	0.8131
West Africa	0.2942	0.0887	0.9785	0.1108	0.4435	0.1479
Central America	0.0189	0.7753	0.0021	0.9441	0.0001	0.9048
Central Asia	0.0004	0.2866	0.8187	0.1026	0.0002	0.2374

interpret this as a sign of integration to global cereal markets. On the other hand, we interpret the lack of Granger causality as a sign of a poorly integrated market. We used the Akaike Information Criterion (AIC) and lag length of 2, and provide these assessments for three combinations of three indices for the five regions.

We considered cointegration using standard tests (see Fackler and Goodwin for a summary listing, 2001), but did not find any cointegration relationships in our data., Cointegration demonstrates long-term relationship between two data sets. The limited length of our data (88 periods) may not allow for a robust assessment of co-integration, but given the standard tests we have done, we did not find the presence of any co-integrating relationships in the data, and were unable to reject the null hypothesis of no-cointegration.

To account for the time-series nature of the data, we first test for stationarity using an augmented Dickey–Fuller (ADF) test (Dickey and Fuller, 1979). Failure to account for the presence of unit-roots in the indices may distort inference and the conclusions we may draw. All of the indices were found to have a unit root. Consequently, all series were transformed into first-differences and retested using the ADF. All of the first-differenced series were found to be stationary in differences, $I(1)$, or integrated of order one.

We use the FAO cereals index to estimate changes in the staple food price indices by country, to provide early warning of price increases in specific food insecure areas. After testing for lags between 1 and 12 months for each country using OLS regression, we estimate regression parameters using the data from 2004 to

Fig. 3. First differences of FAO cereals price index and the regional staple food price index using all commodities and all markets.

2008. We analyze the amount of price dispersion during each time step for each index by calculating the standard deviation of the country indices within the regional index. We plot these standard deviations as error bars around the central index, as well as report the standard deviation of each country index in Table 1.

4. Results and discussion

Five regional price indices for East, Southern and West Africa, Central America and Central Asia are shown in Fig. 2. Each regional index was created using six combinations of commodities and markets:

Commodity selection	Market selection
FAO cereals only (rice, wheat, corn)	Capital city markets
Non-cereals (beans, potatoes, teff, sorghum, millet, cowpea, cassava, yams)	Non-capital city markets
All commodities	All possible markets

The plots show that the non-cereals index dynamics are often quite different from the cereals, particularly in the Central Asia and Southern African region (excludes South Africa). The differences between the capital and non-capital price indices are less marked, with the prices in non-capital cities being more variable, with a standard deviation that is ten percent higher on average than the capital city index over the time period of the study.

Table 3
Regional regression results showing the relationship between the actual and predicted regional staple food price index for all markets and all commodities are presented. Regression parameters are developed for the 2004–2008 period using the FAO staple food price index.

	R-squared	*P*-value	Beta_0 FAO coeff	Beta_1 constant
East Africa	0.82	4.81E−20	0.7675	16.059
Southern Africa	0.64	3.89E−13	0.39104	44.767
West Africa	0.56	6.56E−11	0.29077	70.763
Central America	0.80	1.52E−18	0.52603	49.369
Central Asia	0.71	1.35E−14	0.80885	11.543

Table 4
Regression results of country staple food price index, using all markets and all commodities listed in Table 1. The results of two regression models are presented, one predicting the FEWS NET Regional cereal price index with a lagged FAO cereals index using data from 2004 to 2008, and the second with both a lagged FAO cereals index and the previous growing season's maximum NDVI from 2004 to 2008. The r^2 values represent the relationship between the first difference of the predicted country price index and actual time series. The *P*-value, which measures the significance of the FAO and the FAO and NDVI regression, was derived from a one-tailed *F*-test, and is also given for each country.

Country	FAO index Granger-causes country index *P*-value*	Result	Country index Granger-causes FAO index *P*-value*	Result	*R*-squared FAO[a]	*P*-value FAO	*R*-squared FAO/NDVI	*P*-value – FAO/NDVI
Afghanistan	0.004	Yes	0.3851	No	0.93114	1.23E−33	0.93203	2.97E−32
Burkina Faso	0.221	No	0.413	No	0.01464	0.3656	0.14371	0.01403
Benin	0.271	No	0.1735	No	0.54422	5.91E−11	0.68324	3.31E−14
Burundi	0.54	No	0.8819	No	0.37226	3.69E−07	0.38544	1.53E−06
Côte d'Ivoire	0.316	No	0.4518	No	0.089573	0.034737	0.19904	0.0054313
Chad	0.706	No	0.1645	No	0.10404	0.017371	0.12923	0.029342
Cape Verde	0.153	No	0.0128	Yes	0.75775	2.52E−17	0.76182	2.65E−16
Djibouti	0.049	Yes	0.2864	No	0.93129	4.45E−33	0.93525	3.15E−32
El Salvador	0.038	Yes	0.6293	No	0.87812	2.41E−26	0.88801	6.36E−26
Ethiopia	0.141	No	0.0292	Yes	0.90953	2.26E−30	0.91995	2.46E−30
Gambia	0.366	No	0.6887	No	0.35325	4.26E−06	0.489	1.00E−07
Ghana	0.285	No	0.6066	No	0.63035	4.78E−13	0.71366	7.57E−15
Guatemala	0.385	No	0.2297	No	0.29267	7.19E−05	0.3107	0.0002313
Guinea	0.238	No	0.0043	Yes	0.48221	4.10E−09	0.49559	1.87E−08
Honduras	0.005	Yes	0.6637	No	0.8925	2.48E−27	0.8925	6.56E−26
Haiti	0	Yes	0.3249	No	0.42839	2.51E−08	0.42929	2.00E−07
Kenya	0.735	No	0.3761	No	0.68588	6.48E−14	0.77319	3.43E−16
Mali	0.679	No	0.3045	No	0.11361	0.011856	0.19395	0.0036761
Mauritania	0.009	Yes	0.9568	No	0.78722	8.29E−21	0.80715	9.69E−21
Malawi	0.276	No	0.6286	No	0.7361	1.16E−16	0.74165	1.03E−15
Mozambique	0.8	No	0.3554	No	0.7148	4.04E−14	0.74849	3.26E−14
Nicaragua	0.063	Maybe	0.9051	No	0.88132	1.17E−26	0.89282	1.99E−26
Niger	0.994	No	0.5552	No	0.051693	0.095046	0.36737	6.76E−06
Nigeria	0.367	No	0.0014	Yes	0.24191	0.00024679	0.32189	8.94E−05
North Sudan	0.436	No	0.3505	No	0.024688	0.27583	0.12966	0.038251
Rwanda	0.244	No	0.5055	No	0.59894	1.12E−10	0.59972	1.13E−09
Senegal	0.293	No	0.5071	No	0.8617	2.00E−24	0.87299	5.01E−24
Somalia	0	Yes	0.3493	No	0.89119	1.12E−27	0.90228	1.72E−27
South Sudan	0.43	No	0.899	No	0.42451	2.24E−07	0.6725	2.32E−12
Togo	0.087	Maybe	0.0807	Maybe	0.18928	0.0012676	0.18966	0.0057849
Tajikistan	0.043	Yes	0.3472	No	0.83561	1.98E−22	0.86021	6.06E−23
Tanzania	0.319	No	0.9179	No	0.30481	3.91E−05	0.31669	0.0001571
Uganda	0.274	No	0.5331	No	0.86921	3.53E−24	0.87003	7.02E−23
Yemen	0.007	Yes	0.9887	No	0.3052	2.63E−05	0.45763	4.20E−07
Zambia	0.426	No	0.9304	No	0.4154	4.39E−07	0.47491	2.66E−07

[a] There may be omitted variable bias (we only use 2 regressors). There could be many other specifications to the model.
* All Granger-causality tests conducted using first-differenced data and a lag length of two.

An objective of this study was to determine which regions were more sensitive to variations in rural food prices because of restricted price transmission and significant productive capacity that may affect food prices in the capital cities. We found that of the capital cities used in FEWS NET regional indices, only 35% of them are able to capture 60% or more of the variability of food prices in secondary urban centers and rural areas, suggesting a need for more price data from remote areas that produce food. The correlation between the first differences of the regional capital city price index and an index developed from the remaining non-capital markets for each region is 0.38 for East Africa, 0.08 for Southern Africa, 0.26 for West Africa (Fig. 2C), 0.54 for Central America and 0.37 for Central Asia (Trostle, 2010). These diverse and relatively low correlations demonstrate the ongoing need for continuous monitoring of staple cereal prices in rural markets.

4.1. Market integration

The Granger causality analysis of the regional indices and the FAO cereals index is presented in Table 2. The results suggest that the East Africa, Central America and Central Asia markets are well integrated into the global commodity markets, but that West and Southern African regions are not. Table 2 presents the cereals-only data (maize, wheat and rice), non-cereals and all staple food data for the three different locations within each region – capital cities (similar to the FAO cereals index), non-capitals and all available markets. The results suggest that the cereals-only index is more integrated into the international commodity market in East Africa than prices that are non-cereals, but that when cereals and non-cereals are combined the East African markets are integrated. Non-cereals in East Africa are not Granger caused by the FAO index in the capital cities, but in the non-capitals cereals and non-cereals are Granger-caused. In Central America rice and maize are dominant staples and the geographic extent is small, regional market price indices are integrated into the international markets for all combinations and all markets. West and southern Africa are independent of the FAO index, particularly for non-cereals.

Fig. 3 shows the first differences of the five regions all markets and all commodities indices with the FAO cereals price index. The results show the responsiveness of the regional price indices to FAO index. Table 3 shows the correlation between the predicted prices for 2009–2011, using the regression parameters given derived from the 2004 to 2008 data, and the actual price data from 2009 to 2011. Because the FAO cereals index was used as the predictor variable in these regressions, the regions with the lowest integration into the international markets have the lowest model fit. In these areas, the FAO cereal price index contributes little information useful for estimating regional price variation.

Table 4 shows the results of the Granger causality analysis for the all commodity, all markets for the country price indices. Also presented are the regression results between the FAO cereals index and the country index, as well as the polynomial OLS with both the FAO cereals index and the annual NDVI estimate. The results show that in countries that are integrated with international markets, the OLS regression results are significant, and the NDVI unimportant in the results. This lack of significance does not mean that the weather (as reflected in the health of the vegetation) is not important. It may reflect the fact that price information is much more rapidly transmitted down the marketing chain into market prices in these countries. In a sense, another sign that the markets are well-functioning. On the other hand, when the NDVI is significant, it may mean that information is not completely

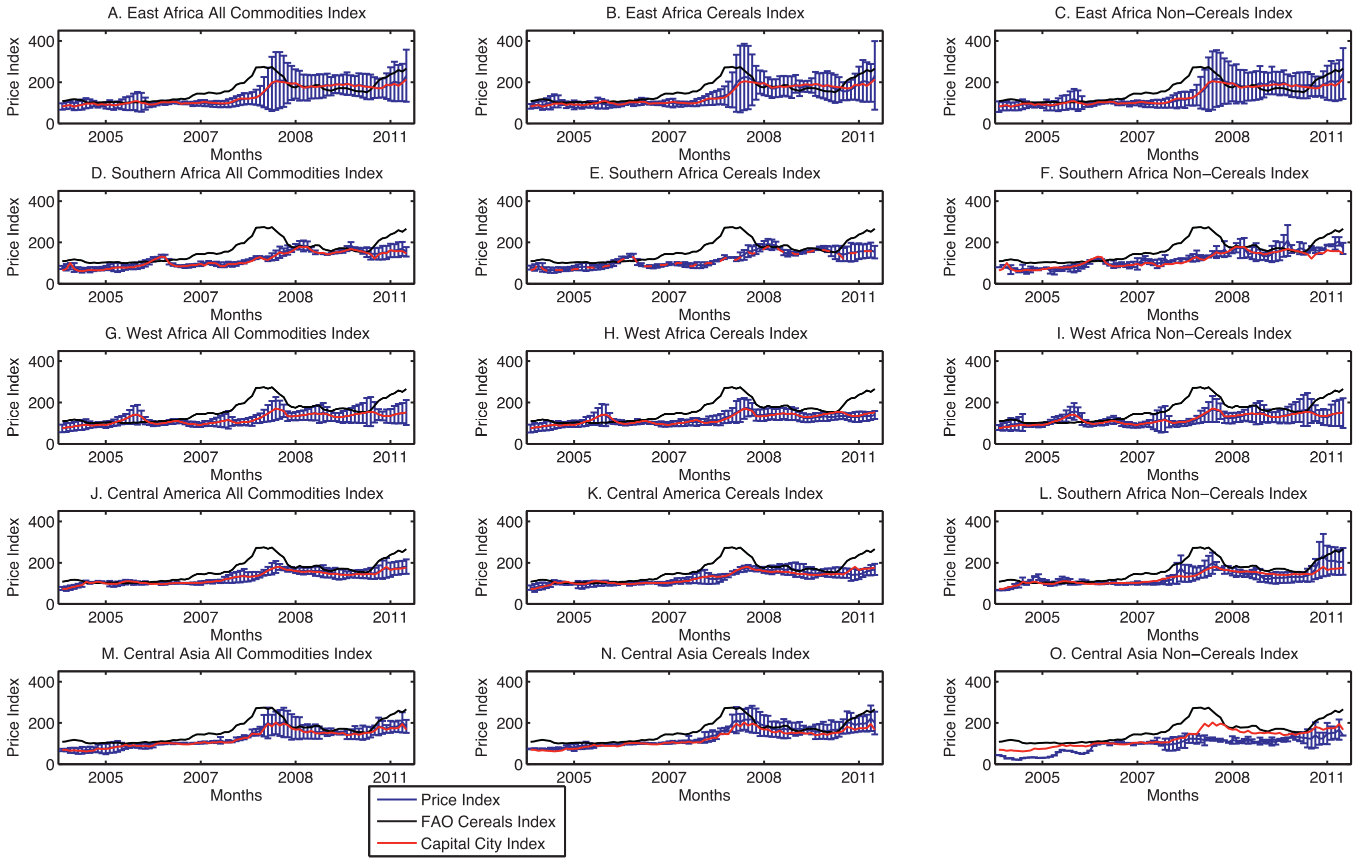

Fig. 4. Regional index price dispersion for regional staple food price index, using all commodities, all markets. Error bars show standard deviation of the country indices within the regional index. The regional price index of capital city markets and FAO cereals index are also shown for comparison.

transmitted down the marketing chain, thus resulting in prices that reflect imperfect information. It is in these countries that NDVI data may greatly aid the food-security analyst.

We found that for 12 of the 35 countries the FAO projection is better than the FAO with NDVI projection post-2008 for 21 months or more (there are 28 months of data left after 2008), and for 17 of the 35 countries the FAO projection is better than the FAO with NDVI projection post-2008 for 14 months or more of the period.

4.2. Price dispersion

If market integration in a region is strong, then prices in different markets should converge within a short period of time. A delay in convergence can be seen by price dispersion across markets. This dispersion may not be a bad sign for food security, as it may reflect the fact that local production is sufficient and that no further gains can be made from arbitrage opportunities. This is particularly true in "good" years, where price dispersion may be present, but because of the low margins (sufficient supply, exorbitant transport costs), trade is limited.

Fig. 4 shows the dispersion of monthly prices for the each region and all commodities, cereals and non-cereals using deviation lines. The plot shows an increase in price dispersion across some regions, particularly East Africa, West Africa and Central Asia as of 2008, the time period of the first global "food price crisis" (Piesse and Thirtle, 2009; Webb, 2010). The crisis thus appears to mark a fundamental shift in the dynamics of regional and global commodity markets (Moseley et al., 2010; Trostle, 2010). Variations in efficiency of transportation, ability to sell goods to the international markets and a variable need for importing food from international markets with higher prices all contribute to variability of local prices (Badiane and Shively, 1998; Deaton and Laroque, 1992; Wodon et al., 2008). Central America and Southern Africa show only a small increase in variability over the period of record. Although these results are interesting, more work needs to be done to understand price variability and transmission from global commodity markets to local staple food prices. This work will require exploration using additional statistical methods that is beyond the scope of this paper.

Lags in staple food price between the international and regional markets in Africa are of considerable concern to policy makers. Urban consumers in countries with significant local production of staple cereal crops face a more complex reaction to sharp increases in global cereal prices. Consumers shift to locally produced non-cereal staple foods (e.g. sorghum, millet, teff, cassava, yams, beans), increasing the price of these goods locally. In coastal cities where higher prices for globally traded cereals are passed through to the consumer quickly, the impact on these local staple foods is the most rapid. Thus local producers of these non-cereal staple foods benefit somewhat from increased global prices, and consumers are affected by the general rise in all food prices, particularly in the poorest segments of society.

5. Conclusions

In this study, we used a continuously updated food price database containing 232 markets in 35 countries to derive new food security-related price indices. Out indices enable the quantification of food access conditions in local, national, and regional marketsheds that experience food insecurity. We examined how cereal and non-cereal commodity prices affect broader food prices in food insecure countries and regions, using a novel commodity basket most relevant to food access for the poor in each country. Local, national and regional cereal prices often lag behind international cereal prices, but if they are sufficiently integrated into the international commodity markets, the prices can be predicted using the FAO cereals index. We found that only Central Asia, Central America and East African markets were integrated into the international commodity markets for cereals, highlighting the need for increased monitoring in the non-integrated regions.

Previous research has highlighted the negative impact of increasing food prices for the food security of the poor (Brown et al., 2009a; FAO, 2008; Funk and Brown, 2009b). As international cereal prices continue to respond to increasing global demand and tight supply, improving our understanding of if and how completely these prices are transmitted to food insecure regions is critical for safeguarding the food security of the poor (FAO, 2008). When localized droughts reduce food supplies, chronic reductions in food access can occur due to elevated prices that can persist over a period of years. This analysis shows that including information about local food growing conditions can help identify markets in which prices may greatly affect conditions of food access for the poor.

Staple food price indices developed specifically for food security analysis that include low-value, bulk, semi-processed commodities can inform decision makers in the humanitarian community of the potential for food price-related food insecurity. This information is of increasing value as a globalization of the food market begins to increase the transmission of price signals from developed countries into less developed countries, and periodic imbalances between global demand and supply of food is becoming more frequent.

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